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The Human Sniff: Application of NVIDIA Index Advanced Rendering Solution in HPC

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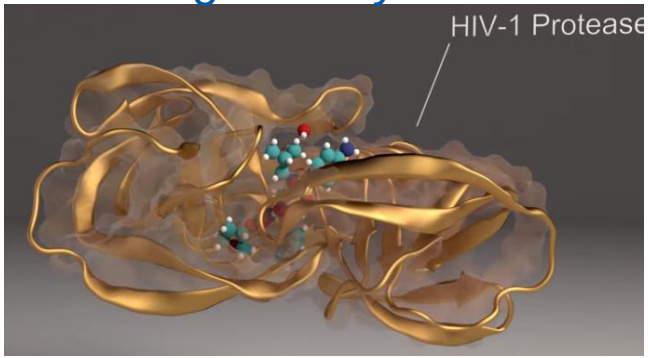
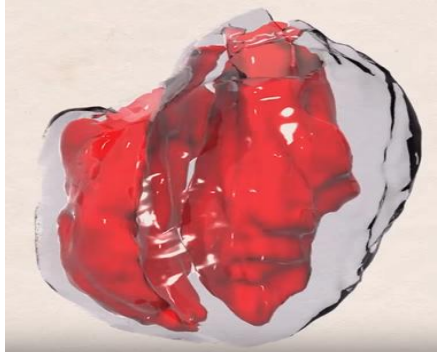
HPC applications @ BSC

Volcanic ash dispersal

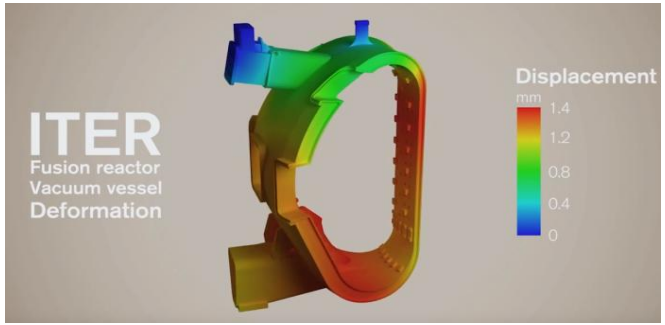
Drug delivery



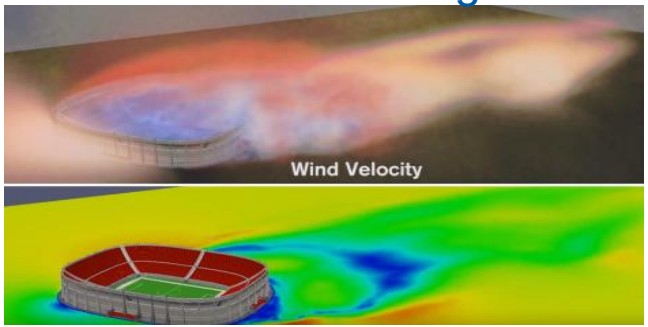
Bio-Mechanics



Fusion Reactor



Climate Modeling



Sniff

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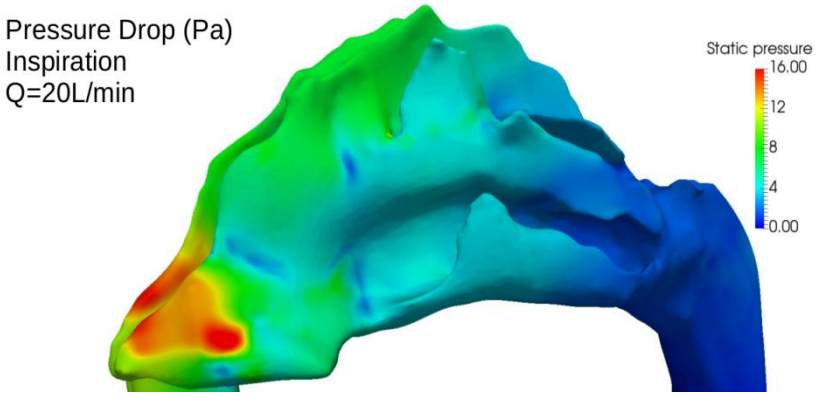
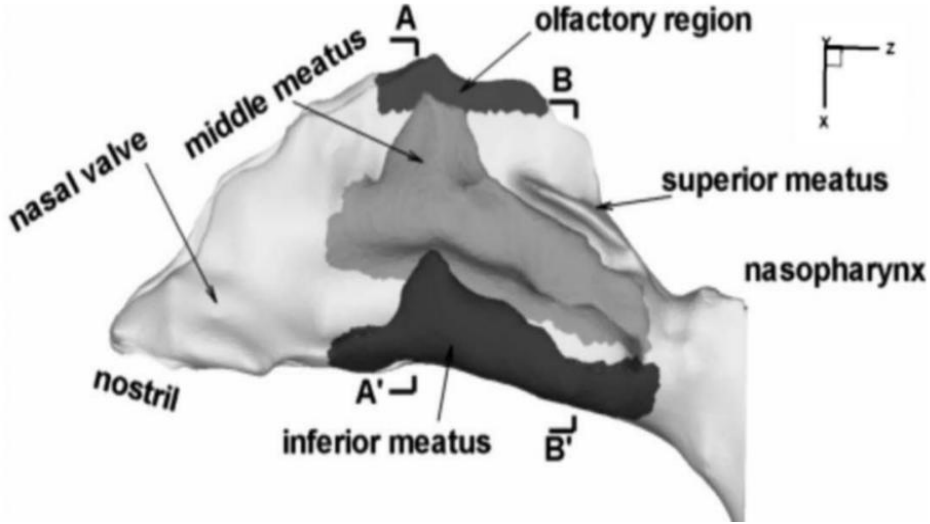
SCIENTIFIC ASPECTS

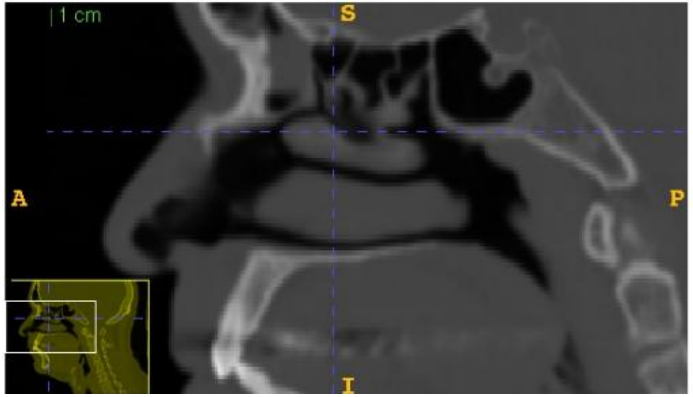
Breathing and Nasal flow

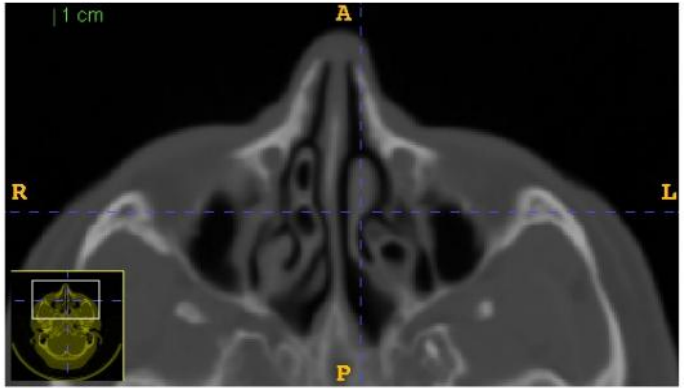


- Normal breathing rate 20-30 l/min, which is around 12,000 liters a day.
- The flow is dominantly laminar due to nasal structures, with turbulences and vortexes a certain locations.
- The air flow rate during breathing can reach 18m/s to 32 m/s during sniff, which the rate of Type one Tropical Cyclone.
- The absolute atmospheric pressure drops almost to zero.

Anatomy and Data Acquisition

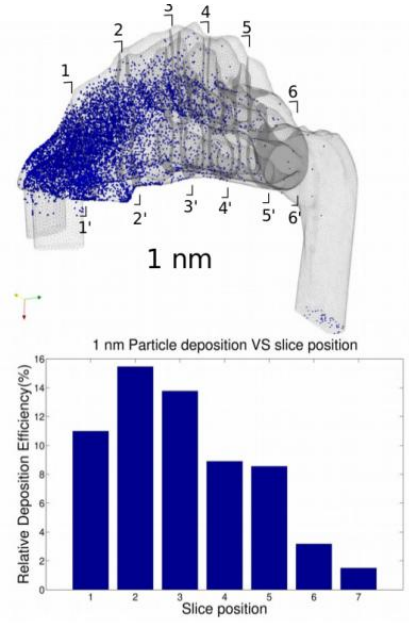


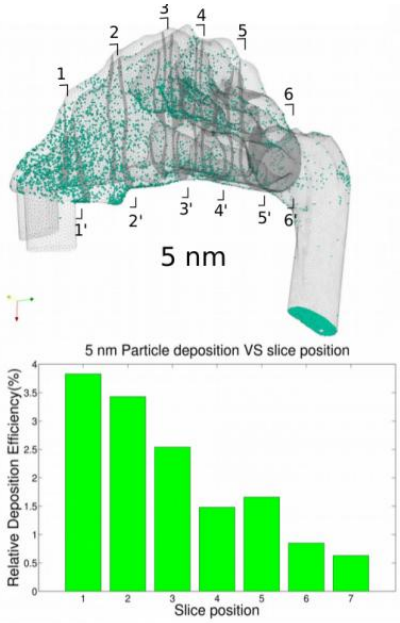


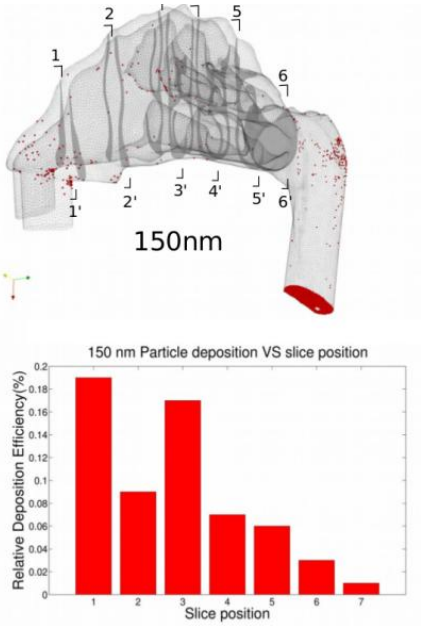


MRI imaging with 0.39x0.39 mm pixel size, slices with 1.3mm thickness and 0.7mm spacing

Deposition and Tracking







- Particles deposition depends on particle size.
- Depends on nasal mucosa level often difficult to simulate
- Particles in nano scale often get drifted by Brownian motion
- Less 2% particles reach the lungs.

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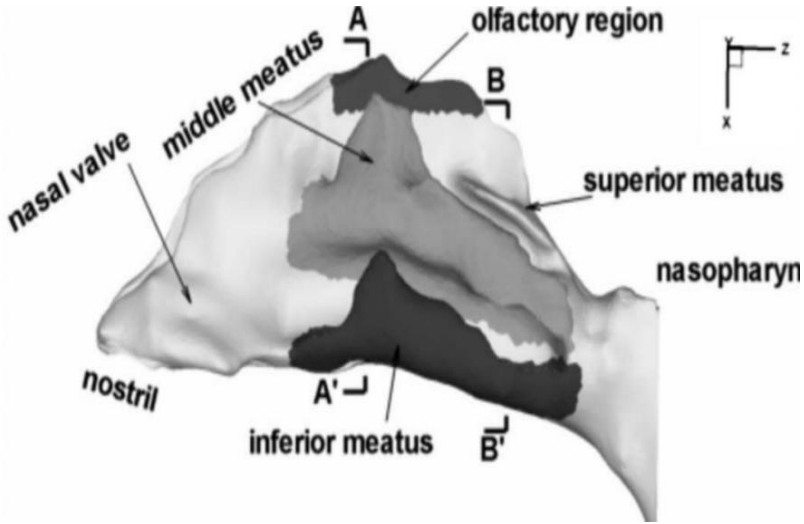
MEDICAL AND PHARMACEUTICAL APPLICATION

Targeted and Efficient delivery



- In most cases a broad particle deposition on mucosal surface in the nasal cavity .
- In sinusitis and nasal polyposis , targeted delivery to the middle and superior meatuses where the sinus openings are, and where the polyps originate is effective.
- Olfactory region is desirable for nose-to-brain delivery.
- Injection into blood stream requires more particles to reach the lungs.

A step towards Personalized Medicine

- Faster and accurate simulations based on patient MRIs, will allow more efficient treatment of chronic diseases.

- Injectors can vary from pipette and catheter for liquid dosage to squeeze bottles and spray pumps.

- Simulations will allow to pick an efficient method of delivery, design personalized injectors and drug composition for targeted delivery.

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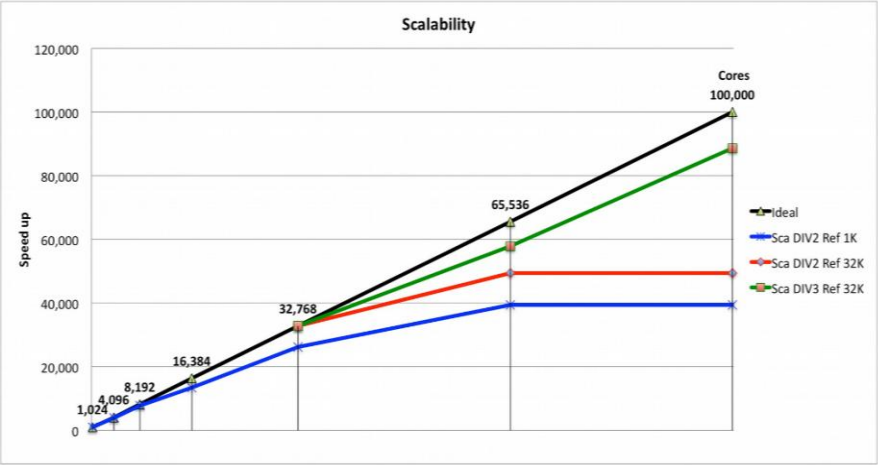
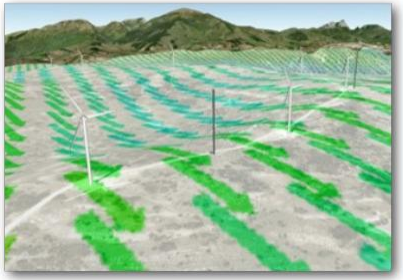
SIMULATION CHALLENGES

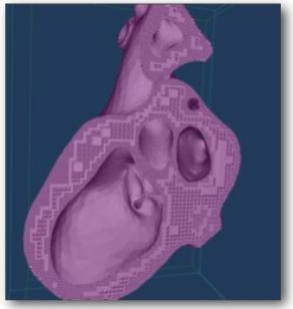
ALYA MultiPhysics

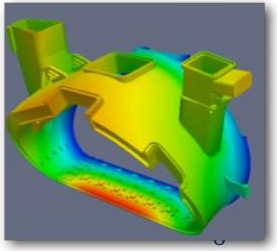
- High Performance Computational Mechanics
- Multiphysics suite
- MPI + OpenMP + CUDA
- Dynamic Load Balancing
- CFD, solid, electromagnetism, combustion, heat transfer, Lagrangian particles, etc.
- One of the two PRACE EU benchmark suite

Blue Waters (NCSA)
4.2 Billions element mesh
Turbulent combustion in a kiln







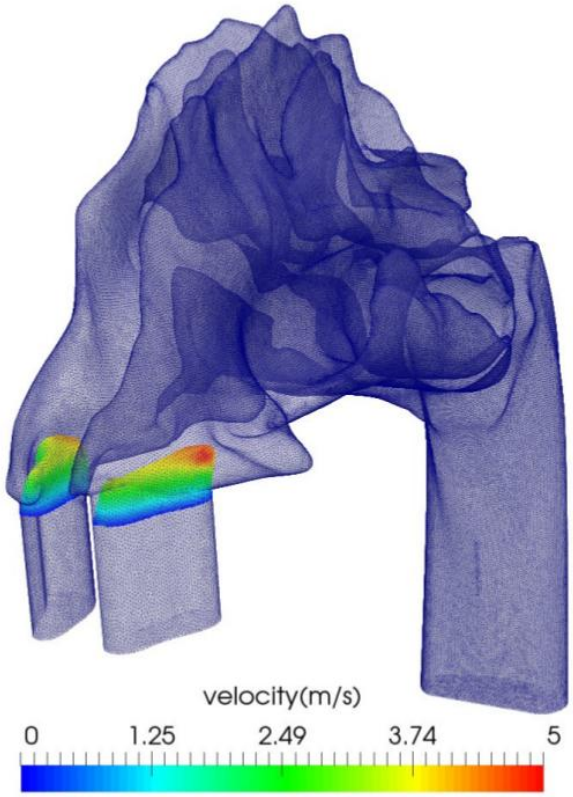


Particles Coupled in ALYA

- Laminar Fluid Flow with active turbulence sites
- Drag force and Brownian motion

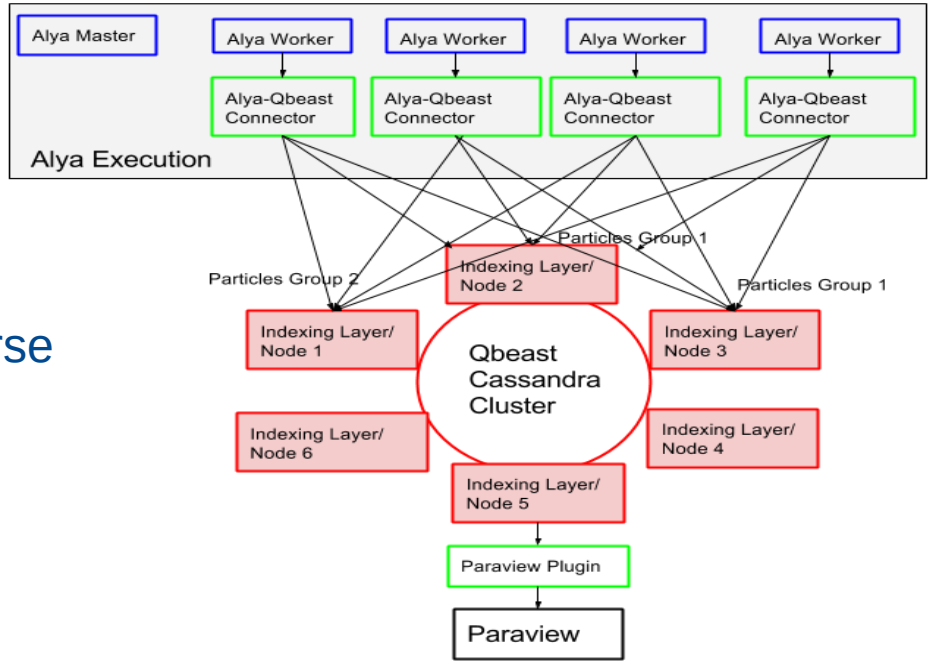
- Semi-implicit Newmark-beta integration scheme (Newton-Raphson)
- Adaptive time step strategy
- Particle diameters ranging from 1 to 150nm

- 50M finite elements and 100k particles.



Big computation and Big data

- A coupled fluid and particle flow takes about 18 hours on 500 nodes (8000 cores).
- It generates about 8-10 Tera bytes of Lagrangian particle information in Sparse volume compressed format.
- Data is stored in key-value format in Cassandra for in-situ analytics.



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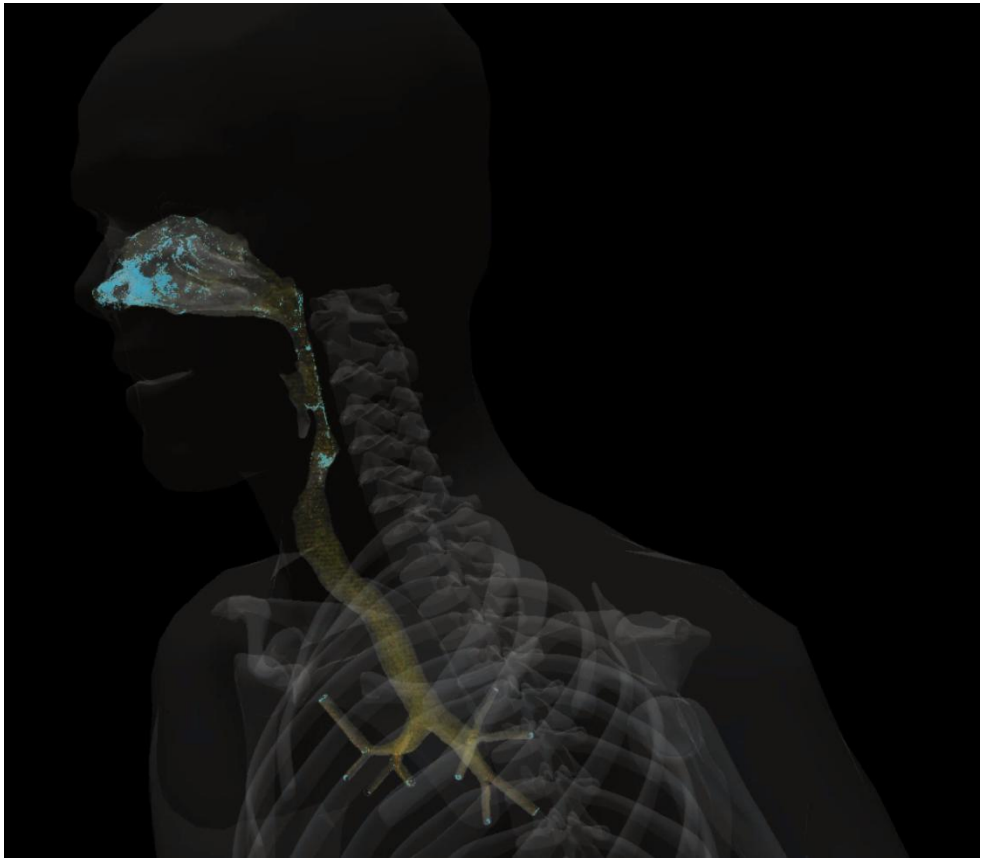
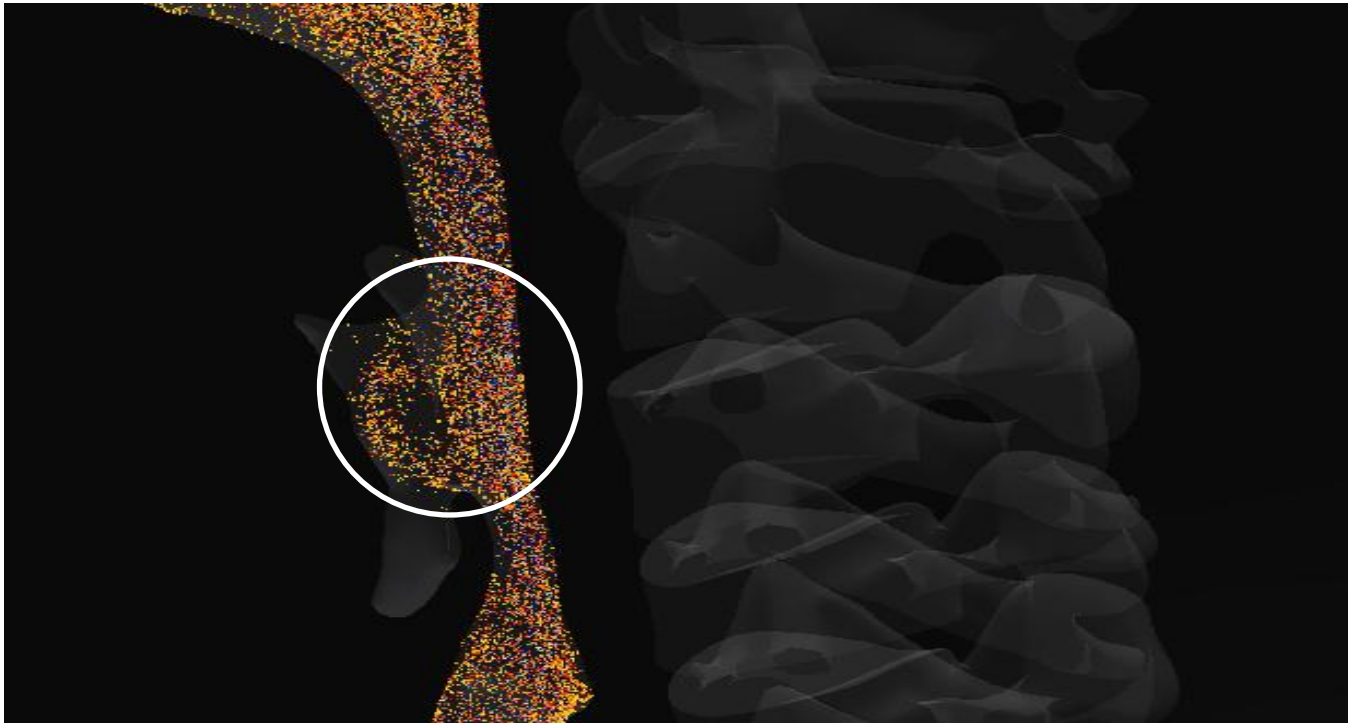
NVIDIA INDEX ADVANCED RENDERING SOLUTION

NVIDIA Index for HPC data:: Big Visualizations

- Parallel Rendering and Composting of Tera Bytes of volumetric data (OpenVDB)
- Allows interactions with the data set, for better insight in the data.
- Supports triangular surface meshes with professional visualization features.

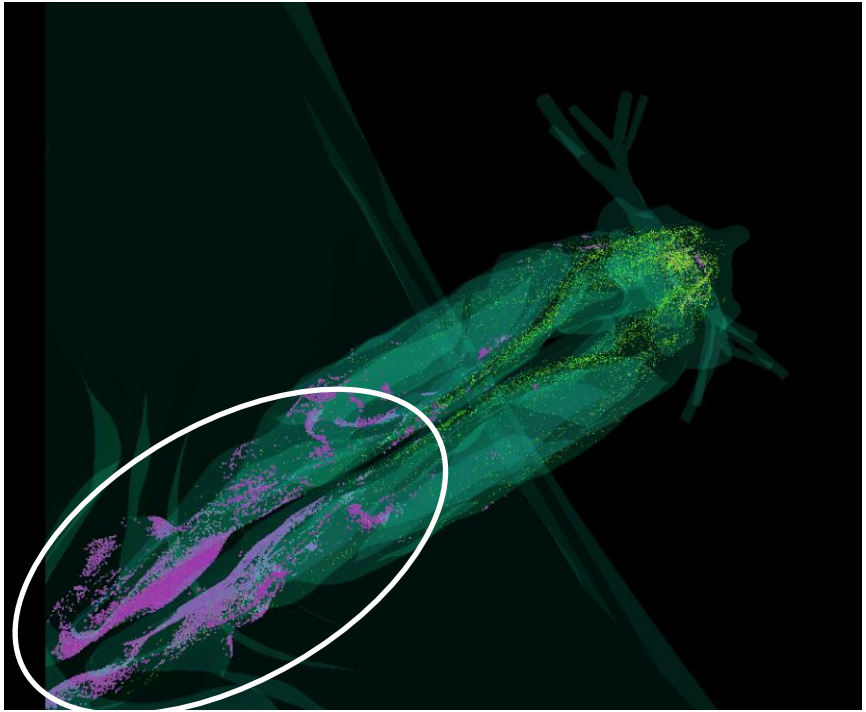


Simulation Features: Re-circulation

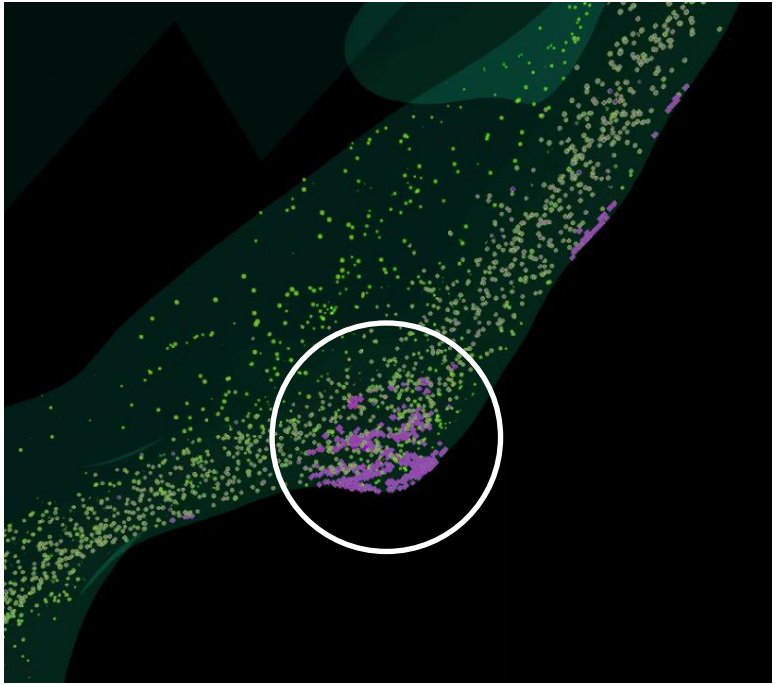


Recirculation in throat, a phenomenon that reduces particle velocities and helps in throat treatment.

Simulation Features: Deposition and Transport



More than 90% particles get deposited in the nasal cavity.



Deposition due to flow in the respiratory track

Summary

- Simulations in targeted medicine application for respiartory system, require massive computation and generates significant quantity of data.
- An ecosystem around in-situ and distributed analytics and visualizations, will reduce time to results.
- Faster simulations, Data analytics, and Visulizations through GPUs is a step towards personalized medicine.

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Thank You
Keep Breathing

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